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FEED INJECTION SYSTEM FOR CATALYTIC CRACKING PROCESS

The present invention relates to feed injection systems and, in particular, to feed nozzles used for catalytic cracking processes.

In a typical Fluid Catalytic Cracking Unit (FCCU) consisting of a regenerator, a riser reactor and a stripper, such as that shown in US-A-5562818 to Hedrick which is incorporated herein by reference, finely divided regenerated catalyst is drawn from the regenerator through the regenerator standpipe and contacts with a hydrocarbon feedstock in a lower portion of a reactor riser. Hydrocarbon feedstock and steam enter the riser through feed nozzles. The mixture of feed, steam and regenerated catalyst, which has a temperature of from about 200 °C to about 700 °C, passes up through the riser reactor, converting the feed into lighter products while a coke layer deposits on the surface of the catalyst. The hydrocarbon vapors and catalyst from the top of the riser are then passed through cyclones to separate spent catalyst from the hydrocarbon vapor product stream. The spent catalyst enters the stripper where steam is introduced to remove hydrocarbon products from the catalyst. The spent catalyst containing coke then passes through a stripper standpipe to enter the regenerator where, in the presence of air and at a temperature of from about 620 °C to about 760 °C, combustion of the coke layer produces regenerated catalyst and flue gas. The flue gas is separated from entrained catalyst in the upper region of the regenerator by cyclones and the regenerated catalyst is returned to the regenerator fluidized bed. The regenerated catalyst is then drawn from the regenerator fluidized bed through the

regenerator standpipe and, in repetition of the previously mentioned cycle, contacts the feedstock in the lower riser.

The most critical element of the FCCU riser reactor design is the feed injection system. For peak performance, it is essential that the feed injection system distributes the feed in fine spray having a uniform coverage across the riser and a narrow droplet size distribution. Such a spray increases the surface area of the feed droplets and facilitates intimate contacting with the regenerated catalyst. Existing feed injection systems of prior art, however, have difficulty in achieving this desired performance.

A typical FCCU can have either side entry nozzles or bottom entry nozzles to introduce the hydrocarbon feed into the riser reactor. Bottom entry nozzles introduce the hydrocarbon feed from the bottom of the riser reactor whereas side entry nozzles introduce the feed from the periphery of the riser reactor and at a higher elevation. Most modern CCUs are designed with side entry nozzles. For FCCUs with side entry configuration, regenerated catalyst is transported upwards from the bottom of the riser by fluidizing gas, usually steam, and the hydrocarbon feed is injected by multiple nozzles mounted on the periphery of the riser reactor at a higher elevation. Modern side entry nozzles, such as disclosed in US-A-5794857 are, in general, good feed atomizers. However, the side entry configuration has several significant drawbacks. The higher feed injection point leads to lower riser reactor volume and lower catalyst circulation, due to higher pressure drop in the riser. The contact of hot, regenerated catalyst with transport steam at the lower riser also leads to higher catalyst deactivation before feed contacting.

Catalytic cracking units with bottom entry nozzles can avoid the drawbacks of the side entry configuration described above. However, prior art bottom entry nozzles are, in general, not as good in feed atomization. US-A-4097243 disclosed a bottom entry nozzle design with multiple tips to distribute feed into multiple streams. Feed atomization was rather poor. In addition, feed was injected in a substantially longitudinal direction of the riser which leads to slow mixing between the feed and the regenerated catalyst because both are moving in a substantially parallel direction. This leads to an undesirable condition of feed contacting with a broad feed vaporization zone in the reactor riser. A number of improvements, such as CA-A-1015004, US-A-4808383, US-A-5017343, US-A-5108583, and EP-A-151882 disclose various means to improve feed atomization for bottom entry nozzles. However, feed atomization remains inadequate, and the feed injection remains substantially longitudinal, leading to slow mixing with regenerator catalyst and undesirable feed contacting in a broad vaporization zone.

US-A-4784328 and EP-A-147664 disclose two complicated designs of mixing boxes at the bottom of the FCCU reactor riser to improve mixing between feed and regenerated catalyst. However, these mixing boxes have a very complicated geometry with many passages which make it difficult to retain their mechanical integrity and proper functions over time because the lower riser region is extremely erosive.

US-A-4795547 and US-A-5562818 disclose two bottom entry nozzles with different designs of diverter cones at the exit of a substantially longitudinal feed pipe carrying atomized feed. The function of these diverter cones is to redirect the substantially axially flowing feed stream to a somewhat radially discharging feed at

the exit, thus intended for enhancing the mixing with the regenerated catalyst. However, there are major drawbacks in these diverter designs. First, the hydrocarbon feed is atomized upstream of the diverter and when the atomized feed impinges on the surface of the diverter cone at the exit, re-coalescence of many of the atomized feed droplets occurs, leading to the formation of sheets of liquid discharging from the cone. The diverter cone achieves a change in the direction of the feed but this comes at the high price of significantly worsening feed atomization. Second, the radially discharging feed in the form of liquid sheets from the diverter cone can penetrate through catalyst in the riser without much vaporization and impinges on the riser wall, leading to major mechanical damage.

The object of the present invention is to provide an improved bottom entry feed injection system for use in catalytic cracking processes which will result in better feed distribution in the reactor riser.

This object is achieved with the following nozzle for use in a fluid catalytic cracking unit comprising:

a first conduit for providing a passageway for enabling a first dispersing gas to flow therethrough;

a first cap covering the end of said first conduit, said first cap including at least one outlet passageway therethrough adapted for discharging said first dispersing gas into a liquid hydrocarbon feed material;

a second conduit enclosing said first conduit and spaced therefrom to form an annulus therebetween thereby providing a passageway for enabling said liquid hydrocarbon feed material to flow therethrough;

a second cap covering the end of said second conduit, said second cap being spaced from said first

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cap thereby forming a mixing zone therebetween for mixing said liquid hydrocarbon feed and said first dispersing gas said and said second cap including at least one circular slot as outlet passageway therethrough, which passageway is substantially aligned with the outlet passageway on said first cap and is adapted for discharging said mixture of said liquid hydrocarbon feed and said first dispersing gas, and

wherein a third conduit is present surrounding said second conduit and forming an annulus therebetween for providing a passageway for enabling a second dispersing gas to flow therethrough.

The present invention improves feed atomization of bottom entry injection systems, thus eliminating the need for a side entry configuration and its drawbacks. It has been found that the bottom entry feed injection system of the instant invention achieves an improved feed atomization and distribution achieving a uniform feed distribution across the riser. The present feed injection system will distribute the hydrocarbon feed in a fine spray having a uniform coverage across the riser and a narrow droplet size distribution. Another advantage is that the atomized feed can be discharged in a substantially radial direction for better mixing with regenerated catalyst, without having to use a diverter cone. A further advantage is that the atomized feed can be discharged in a substantially radial direction, while not impinging the riser wall.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a preferred embodiment of a FCCU with a single bottom entry feed injection system.

FIGURES 2A/2B/2C show detail design features of the preferred feed injection system of Figure 1.

FIGURE 3 shows a prior art single bottom entry feed injection system.

FIGURE 4A shows a plan view of feed distribution in the riser of prior art side entry feed nozzles.

FIGURE 4B shows a plan view of improved feed distribution provided by a single nozzle according to the present invention.

FIGURES 5A/5B show detail design features of an even more preferred feed injection system of Figure 2A/2B/2C.

FIGURES 6 and 7 show detail design features of another preferred feed injection system of Figure 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to Figure 1 which shows a preferred embodiment of the present invention, a catalytic cracker riser reactor 1 is connected to a regenerator standpipe 2 through which hot, regenerated catalyst 3 enters the riser bottom region. A liquid hydrocarbon feed 8, such as gas oil, and dispersing gas 4 and 12, such as steam, are introduced through a single bottom entry nozzle assembly 100.

Preferably the nozzle is provided with a third conduit, as shown in Figure 1 as conduit 5. The third conduit surrounds the second conduit 38 and forms an annulus 6 therebetween for providing a passageway for enabling a second dispersing gas to flow therethrough.

Nozzle assembly 100 comprises three concentrically and substantially vertically arranged conduits. A first conduit 22 provides a passageway for a first dispersing gas 12 and terminates in a first cap 32. First conduit 22 and first cap 32 are surrounded by a second conduit 38 terminating in a second cap 48, the annulus 9 formed thereby providing a passageway for liquid hydrocarbon feed 8. Second conduit 38 is, in turn, surrounded by a third conduit 5 which is open at the top. The external surface of conduit 5 is protected by an erosion resistant material 7, such as refractory or other material known to those skilled in the art, to prevent damage to the nozzle assembly 100 by the incoming hot, regenerator catalyst 3. The external surface of the second cap 48, extending beyond the termination of conduit 5 and into riser reactor 1, is protected by erosion resistant material, such as STELLITE 6 (STELLITE is a trade mark) or other

material known to those skilled in the art. A first annulus 6 is formed between conduit 5 and conduit 38. A second annulus 9 is formed between conduit 38 and conduit 22. Centering lugs 10 in the first annulus 6 keep conduit 38 centered within conduit 5. Centering lugs 13 in the second annulus 9 keep conduit 22 centered within conduit 38.

A first dispersing gas 12 enters first conduit 22 which terminates with a first cap 32 having at least one outlet passage 14 discharging in generally a radially outward and, preferably upward, direction into mixing zone 42, located in the vicinity of the discharge of outlet passage 14 between first cap 32 and second cap 48. Liquid hydrocarbon feed 8 enters conduit 28, continues through substantially vertical second conduit 38 via annulus 9 to a second cap 48 and is mixed in a cross-flow with the first dispersing gas 12 in mixing zone 42, resulting in the formation of a fine two-phase mixture of small dispersed bubbles in heavy petroleum hydrocarbon liquid. Second cap 48 has at least one circular slot outlet passage 11 for emitting the mixture of hydrocarbon feed and first dispersing gas into the riser reactor 1 in a radially outward and, preferably upward, direction. Passage 11 is substantially aligned with the discharge of the first dispersing gas 12 from outlet passage 14. As the fine two-phase mixture of small dispersed bubbles in heavy petroleum hydrocarbon passes through outlet passage 11 into riser reactor 1 to contact with regenerator catalyst 3, the two-phase mixture suddenly expands, forming a hollow cone fine of atomization of heavy petroleum hydrocarbon feed with narrow droplet size evenly distributed across the riser reactor 1.

Conduit 5 penetrates through the riser bottom 30 into riser 1 and terminates at a level 15 preferably above the center line 2a of regenerator standpipe 2. A second

dispersing gas 4 passes through conduit 24, and is directed into conduit 5 via the first annulus 6 and exits through the top of conduit 5 into the riser reactor 1 in a substantially longitudinal direction. The second dispersing gas 4 has several functions. One is to shield hot, regenerated catalyst 3 from damaging the feed injection nozzle 100 inside conduit 5 under normal operation. Another function is to provide emergency fluidization gas for transporting catalyst in case of feed outage.

Additional dispersing gas 16 can be suitably introduced though conduit 26 to assist fluidization in the lower riser region. In Figure 1, conduit 26 is shown connected to a single distribution ring 17 surrounding conduit 5 and having multiple nozzles 18. Other means known in the art, such as a perforated plate, can be used for distributing the additional dispersing gas 16. Although Figure 1 shows an embodiment with only a single injection nozzle assembly 100, other arrangements, such as multiple feed assemblies 100 in a riser reactor, with each feed assembly 100 emitting at least one conical formed spray from outlet passage 11, can be used to achieve the same objective for large FCCUs with higher hydrocarbon feed rates. The number of feed nozzle assemblies 100 in a single riser can be any reasonable number, but is preferred to be in the range of one to six.

Figures 2A, 2B and 2C show details of the caps 32 and 48 which terminate conduits 22 and 38 respectively at the end of feed injection assembly 100 in the preferred embodiment of Figure 1. Figure 2A is a cross-sectional view, taken along the line 2A-2A of Figure 1, of the conduits 22, 38 with their respective caps 32, 48 and conduit 5 with protection material 7. The first dispersing gas 12 passes through conduit 22 to first

cap 32 and exits at dispersing gas outlet passages 14 into the mixing zone 42 which is in the vicinity of the discharge of outlet passage 14, between caps 32 and 48, and upstream of circular slot outlet discharge 11. The outlet passage 14 is shown to be on conical surface 35 of cap 32 such that the first dispersion gas 12 is discharged through passage 14 in a generally radial outward and, preferably upward, direction and mixed in a cross-flow with liquid hydrocarbon feed in the mixing zone 42. The upward discharge angle of passage 14 is more preferably in a range of 10° to 90° from the axis of nozzle assembly 100, and most preferably in the range of 20° to 80° from the axis of nozzle assembly 100. The resulting angle 33 of the conical surface 35 of first cap 32 of the embodiments illustrated by the Figures can then suitably be in a range of 100° to 170°, and preferably in the range of 110° to 160°. The amount of first dispersing gas 12 can be in the range of 0.2 to 7 weight percent of the hydrocarbon feed 8, but is preferably in the range of 0.5 to 5 weight percent of the hydrocarbon feed 8. The discharge velocity of first dispersing gas 12 through passage 14 can be in the range of 15.2 and 244 m/s (50 to 800 ft/sec), but is preferably in the range of 30.4 and 152 m/s (100 to 500 ft/sec). The hydrocarbon feed 8 passes through conduit 38 via annulus 9 to cap 48 and mixes in a cross-flow with the dispersing gas 12 from passages 14 in the mixing zone 42, resulting in the formation of a fine two-phase mixture of small steam bubbles in the liquid hydrocarbon just upstream of passage 11 which is substantially aligned with the first dispersing gas outlet passage 14. The substantial alignment of passages 14 and 11 assures that the fine two-phase mixture of small steam bubbles in the liquid hydrocarbon passes through passage 11 as soon as

the mixture is formed in the mixing zone 42, thus minimizing the tendency of re-coalescence and maximizing energy efficiency of the first dispersing gas for atomization. As the fine two-phase mixture of small steam bubbles in the liquid hydrocarbon passes through outlet passages 11 into the riser reactor 1, the two-phase mixture suddenly expands, due to the pressure drop through passage 11, resulting in the formation of a fine atomization of hydrocarbon feed 8 with narrow droplet size distribution and even distribution. The pressure drop through passages 11 can be in the range of 0.689 and 6.89 bar (10 to 100 psi), but is preferably in the range of 1.38 and 4.8 bar (20 to 70 psi). Outlet passage 11 is shown to have a chamfer 41 at the end of the passage 11 to assist the sudden radial expansion of two-phase flow and the fine atomization of hydrocarbon feed 8 into the riser reactor 1. Preferably the chamfer 41 has an angle between 0° and 40° and more preferably between 0° and 10° with the outlet passage 11. Cap 48 and outlet passage 11 can include a protection layer 50, such as STELLITE or other material known to those skilled in the art, to prevent damage by the catalyst. The outlet passage 11 is shown to be on a conical surface 45 of cap 48 such that the mixture of first dispersion gas 12 and liquid hydrocarbon 8 is discharged through passage 11 in generally a radially outward and, preferably upward, direction. As described above for the upward discharge angle of passage 14, the corresponding upward discharge angle of passage 11 is also preferably in a range of 10° to 90° from the axis of nozzle assembly 100, and more preferably in the range of 20° to 80° from the axis of nozzle assembly 100. The resulting angle 43 of the conical surface 45 of cap 48 of the embodiments illustrated by the Figures can then suitably be in a

range of 100° to 170°, but is preferably in the range of 110° to 160°. Preferably conical surface 35 and 45 are arranged parallel with respect to each other as shown in this Figure. Although caps 32 and 48 are shown to include conical surfaces 35 and 45, respectively, other types of surfaces, such as spherical or elliptical surfaces, can be included on caps 32 and 48 as long as passages 14 and 11 can be positioned on these surfaces so as to discharge the first dispersion steam 12 and hydrocarbon feed 8 in generally a radially outward and, preferably upward, direction.

Figure 2B shows a plan view of the second cap 48 located at the end of hydrocarbon conduit 38. Cap 48 is shown to have a circular slot consisting of four elongated, curved outlet passages 11 on conical surface 45 as an example for emitting a conical formed spray consisting of four individual fan sprays of mixtures of first dispersing gas 12 and hydrocarbon feed 8 in a radially outward and upward direction into the riser 1. The angle of each of the fan sprays, as seen from above, emitted from one single passage 11 can be in the range of 30° to 120°, preferably in the range of 60° to 100°.

Figure 2C shows a plan view of the first cap 32 located at the end of the first dispersing gas conduit 22. Cap 32 is shown as having four groups of circular outlet passages 14 on conical surface 35 arranged in four curved lines behind, and substantially aligned with, passages 11 of Figure 2B. Although each group of dispersing gas outlet passages 14 is shown to consist of six substantially round passages for each individual fan spray emitted from passages 11, the number of passages 14 in each group could be any reasonable number. The total number of passages 14 present on cap 32 will depend on the size of the feed nozzle assembly and can suitably vary between 40 and 300.

Figure 5A shows a plan view of the second cap 48 located at the end of hydrocarbon conduit 38 as in Figure 2B. It has been found advantageous that the annular outlet passage 11 is open along its entire circumferential as illustrated in Figure 5A. In Figure 2B the circular slot is divided by four bridges resulting in four separate passageways 11. By reducing or omitting the bridges, of Figure 2B, one single circular slot opening and one single conical formed spray results. This is advantageous to achieve a more uniform and unobstructed flow of the mixture of first dispersing gas 12 and hydrocarbon feed 8 into riser 1. Optionally, but less preferred, a plurality of concentric slots can be used as passageways 11.

Preferably the gas outlet passages 14 in first cap 32 are arranged in one circular line behind and substantially aligned with passage 11 as shown in Figure 5B. Preferably outlet passages 14 constitute one single group as shown in Figure 5B, in contrast with the different groups of outlet passages as shown in Figure 2C. This one group of outlet passages 14 may be arranged along one or more concentric lines on first cap 32. Figure 5B illustrates two concentric lines of passageways 14.

Figure 6 shows a nozzle assembly 100 provided with a passageway 55 for enabling part of the liquid hydrocarbon feed material to be discharged in a more central position, between the first cap 32 and second cap 48, than the position of the outlet passageways 14 of said first cap 32. In such a preferred design liquid hydrocarbon feed material will flow from at least two directions to the mixing zone 42 present between passageways 11 and 14. One direction is a flow from a central region 56 between caps 32 and 48 and the other direction is a flow directly from annulus 9. It has been

found that by introducing the hydrocarbon feed material to the mixing zone 42 in this manner an even more uniform mixing of first dispersing gas and hydrocarbon feed results. In a most preferred embodiment a substantially equal flow of hydrocarbons flow from either side to mixing zone 42 exists. In some practical embodiments this volume flow ratio of central and annular flow may suitably vary between 1 and 5. The hydrocarbon feed material supplied to the central region 56 can be fed via a separate supply conduit present in conduit 22, wherein this hydrocarbon feed rate can be suitably externally controlled.

Preferably part of the hydrocarbon feed material is fed to the central region 56 as shown in Figure 6. Figure 6 shows an embodiment wherein one or more conduits 55 fluidly connect the central region 56 between second cap 48 and first cap 32 via inlet opening 58 with the lower part of annulus 9. The outlet openings 57 of conduits 55 are more centrally located than the mixing zone 42 and the passageways 14 on said first cap 32. Preferably the ratio of the total cross sectional area of all conduits 55 and the smallest area of the annulus 9 is between 1:1 and 1:5. The number of conduits 55 can be between 1 and 15. A too large number will not be beneficial to the mechanical strength of the nozzle. A too low number will not achieve the desired mixing effect. A preferred number of passageways 55 is from 4 to and including 8.

The second cap 48 can be fixed onto the nozzle 100 by means of one or more fixing means 59, for example by means of a bolt or welded pin, connecting the second cap with the first cap 32.

Figure 7 shows a first cap 32 of Figure 6 as seen from above, provided with five outlet openings 57 and two concentric lines of passageways 14 and fixing means 59.

The major improvement of the present invention over the prior art bottom entry nozzles, such as disclosed in US-A-4795547, is much better feed atomization and riser reliability. In the prior art of US-A-4795547, shown in Figure 3, the hydrocarbon enters through conduit 5 and single phase atomization nozzle 11 and dispersing gas enters through conduit 4 and annulus 6. Feed atomization occurs as the feed exits single phase atomization nozzle 11, far upstream from the exit into the riser 2. The feed from nozzle 11 and the dispersing gas in annulus 6 are both moving in a substantially axial direction with very little cross-flow mixing between the two. The atomized feed droplets are then conveyed in substantially longitudinal flow, by the dispersing gas entering through conduit 4, and impinge on the exit deflection cone 13 which suddenly alters the direction of the feed droplets from substantially longitudinal flow to radially outward and upward.

The improvements of the present invention over the prior art of US-A-4795547 includes:

Two phase atomization vs. single phase atomization: In US-A-4795547, feed atomization occurs mostly through a single-phase atomization nozzle 11 as shown in Figure 3 which is far less efficient compared to the present invention using a two-fluid atomizer through caps 32 and 48 in Figure 1.

Atomization at the exit vs. upstream atomization: In US-A-4795547, feed atomization occurs mostly through a single-phase atomization nozzle 11 shown in Figure 3 far upstream of the final exit. As the atomized feed droplets are conveyed by the dispersing gas, droplets can coalesce on the surface of the conveying conduit leading to poor atomization. In the present invention, feed atomization occurs at the very exit by aligning first dispersing gas outlet passage 14 with passage 11, forming a fine two-

phase mixture of small steam bubbles in the liquid hydrocarbon by cross-flow mixing in mixing zone 42 between caps 32 and 48 just upstream of passage 11, and passing the two-phase mixture through outlet passages 11 for fine atomization. There is no conveying conduit with atomized droplets which could lead to re-coalescence.

Direct discharge vs. diverter cone: In US-A-4795547, a diverter cone at the exit is used to suddenly alter the direction of the feed droplets from substantially longitudinal flow to radially outward and upward. This leads to impingement of droplets on the cone surface and significant worsening of atomization. In the present invention, feed atomization occurs at the exit of caps 32 and 48 which direct the first dispersing gas 12 and the mixture of the first dispersing gas 12 and liquid hydrocarbon feed 8 in substantially radial directions through passages 14 and 11. There is no diverter cone or sudden direction change of atomized feed which could lead to re-coalescence.

Because of the improvement in feed atomization by the present invention over the prior art bottom entry nozzles, such as of US-A-4795547, the jet penetration of hydrocarbon feed emitted in a radially outward direction into the riser is shorter with the present invention. This prevents the riser damage caused by direct impingement of hydrocarbon feed which is known to occur with the prior art bottom entry nozzles, such as of US-A-4795547, which discharges hydrocarbon feed in a sheet of liquid.

Atomization of two nozzles, one according to the present invention of Figures 1 and 2 and the other according to the prior art of US-A-4795547 patent, shown as Figure 3 herein, were tested in ambient condition using air to simulate the dispersing gas and water to simulate the hydrocarbon feed. Test results confirm that

the nozzle of the present invention has much better atomization, compared to the prior art of US-A-4795547 patent. The average droplet size generated by the nozzle of the present invention was about 1/3 of the prior art design of US-A-4795547 patent under the same operating conditions. Test results also confirm that the nozzle of the present invention has shorter jet penetration, compared to the prior art of US-A-4795547 patent.

The major improvements of the present invention over the prior art of side entry nozzles, such as US-A-5794857 to Chen et al., are that adequate feed atomization can be achieved by the present invention of the improved bottom entry nozzle, thus overcoming the need for using side entry nozzles and the associated drawbacks of lower riser volume, higher catalyst deactivation and lower catalyst circulation. The cost of installing the improved bottom entry nozzle of the present invention is also much lower compared to typical side entry nozzles. Furthermore, a better feed distribution across the riser reactor can be achieved with the present invention when compared to typical multiple side entry nozzles of prior art. This is demonstrated by Figure 4A which shows a plan view of typical prior art feed distribution in a cross section of the riser using four side entry nozzles of prior art, such as US-A-5794857, spaced 90° apart, emitting four fan jets radially inward, having an angle of 95° from each fan spray. Figure 4A shows that substantial areas, shown as the double-shaded areas 44, are covered by overlapping spray patterns from adjacent nozzles. It also shows that substantial areas, shown as blank areas 46, are not covered at all by any of the four fan sprays. The combination of these two features leads to undesirable results of uneven feed distribution by the prior art of typical side entry nozzles where some areas in the riser have no feed coverage at all and some areas have too much

feed. Figure 4B shows the feed distribution patterns in a cross-section of the riser reactor for a single bottom entry feed nozzle emitting four fan sprays radially outward, spaced 90° apart, according to the embodiment of Figures 1 and 2 with four outlet passages 11. Each fan spray emitted from the passages 11 has an angle of 95°. It is shown that, with exactly the same number of jets and the same spray angle as the prior art side entry nozzles, but changing the feed injection from radially inward in Figure 4A to radially outward in Figure 4B, most of the riser reactor area is evenly covered by the present invention and there is no overlapping of adjacent fan sprays. This clearly demonstrates that the present invention has superior feed distribution when compared to the typical feed distribution of prior art side entry nozzles, such as US-A-5794857 to Chen et al.

EXAMPLE

A single bottom entry nozzle according to the present invention of Figure 1 was installed in one of Assignee's FCC units which originally had a single bottom entry nozzle according to the prior art, shown in Figure 2 of US-A-4795547 patent, reproduced as Figure 3 herein.

Operating conditions of the FCCU, before and after the revamp, are listed in Table 1:

TABLE 1

		Average Post Revamp	Average Pre Revamp	Delta
PROCESS CONDITIONS				
Feed Rate	ton/day	5281.3	5185.8	95.5
Feed Temperature	ton/day	268.7	260.3	8.4
First dispersion Steam	ton/day	80.0	36.9	44.1
Second dispersion Steam	ton/day	11.5	11.5	0
Additional dispersing Steam	ton/day	24.2	18.6	5.6
Reactor Temperature	°C	494.2	493.2	1.1
Regen Temperature	°C	700.9	697.2	3.8
Liftpot Pressure	barg	2.0	2.2	-0.2
Reactor Pressure	barg	1.8	1.9	-0.2
Regen Pressure	barg	2.0	2.2	-0.2
Cat Circulation Rate	ton/min	17.7	17.9	-0.2

The performance of the FCCU, before and after the revamp, are listed in Table 2:

TABLE 2

	Average Pre Revamp	Average Post Revamp Delta Wt.% of Feed
C2-	base case	-0.2
LPG	base case	-1.1
Gasoline	base case	1.1
Light cycle oil	base case	1.2
Heavy cycle oil & slurry	base case	-1.3
Coke	base case	0.0

The data show that the present invention improves the FCCU performance by reducing the low value products of C2- dry gas, LPG and the combination of heavy cycle oil and slurry by 0.2, 1.1 and 1.3 weight %, respectively,

and increasing high value products of gasoline and light cycle oil by 1.1 and 1.2 weight %, respectively. In addition to the benefit of producing more valuable products, the FCCU also processed 1.9% more feed, as shown in the previous table of operating conditions.